TACTILE SENSORY SUPPLEMENTATION OF GRAVITOINERTIAL REFERENCES TO OPTIMIZE SENSORIMOTOR RECOVERY

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INTRODUCTION

Integration of multi-sensory inputs to detect tilts relative to gravity is critical for sensorimotor control of upright orientation. Displaying body orientation using electrotactile feedback to the tongue has been developed by Bach-y-Rita and colleagues as a sensory aid to maintain upright stance with impaired vestibular feedback. This investigation has explored the effects of Tongue Elecrotactile Feedback (TEF) for control of posture and movement as a sensorimotor countermeasure, specifically addressing the optimal location of movement sensors.

METHODS

TEF of pitch and roll orientation was derived from a two-axis linear accelerometer and displayed on a 144-point electrotactile array held against the anterior dorsal tongue (BrainPort, Wicab, Inc., Middleton, WI). The purpose of ***Specific Aim 1*** (SA1) was to compare postural performance when providing orientation cues via TEF using sensors attached either to a head band or torso belt. Postural equilibrium was measured with a computerized hydraulic platform in 12 healthy adults (7M, 5F). Trials (100 s duration with eyes closed) were conducted with the support surface fixed, sway-referenced, during sum-of-sines perturbations or during a combination of sway-referencing and sum-of-sines perturbations. Sway-referencing was performed with the platform rotating equal to AP sway angle, by translating the support surface proportional to AP sway, or by rotating and translating the support surface. Subjects were required to keep the intraoral display in their mouths on all trials, including those that did not provide tactile feedback. MacDougall et al. (2006) recently demonstrated that unpredictably varying Galvanic vestibular stimulation (GVS) significantly increased anterior-posterior (AP) sway during rotational sway referencing with eyes closed. The purpose of ***Specific Aim 2*** was to assess the influence of TEF on postural control performance with pseudorandom binaural bipolar GVS. Postural equilibrium was measured with a computerized hydraulic platform in 10 healthy adults (6M, 4F) with the linear accelerometers mounted on the torso belt. Subjects performed 24 randomized trials (20 s duration with eyes closed) including four support surface conditions (fixed, rotational sway-referenced, translating the support surface proportional to AP sway, and combined rotational-translational sway-referencing), each repeated twice with and without GVS, and with combined GVS and TEF. Postural performance for both SA1 and SA2 was assessed using deviations from upright and convergence toward stability limits. The purpose of ***Specific Aim 3*** was to evaluate the efficacy of TEF to improve gaze stabilization during walking. Dynamic Visual Acuity (DVA) performance was measured in 10 healthy adults (6M, 4F) during treadmill walking (3mph) using sensors attached either to the head band or torso belt as with SA1.

RESULTS

SA1: As expected, there were improvements in postural performance, based on peak-to-peak AP sway, when using the TEF. The largest changes in postural performance occurred with the platform in the translate sway-referenced mode with or without support surface rotation. In this case, the peak-to-peak sway was significantly reduced with the accelerometers (sensors) mounted on the torso. **SA2**: Postural stability was impaired with GVS in all platform conditions, with larger decrements in performance during trials with rotation sway-referencing. TEF improved performance with GVS toward non-GVS levels, again with the greatest improvement during trials with rotation sway-referencing. These results demonstrate the effectiveness of tongue electrotactile feedback in providing sensory substitution to maintain postural stability with distorted vestibular input. **SA3**: Similar to the posturography results from SA1, there was a trend for improved dynamic visual acuity during treadmill walking to be improved with TEF with the sensor mounted on the trunk.

DISCUSSION

We conclude that locating sensors on the torso may be advantageous for sensory supplementation type countermeasures in conditions that naturally involve head-on-trunk motion, such as counter-rotation of the head during fore-aft translational movements or locomotion. These results suggest that the effectiveness of tactile sensory supplementation for balance prosthesis and vestibular rehabilitation applications may be optimized by accounting for the body segment orientation needed for specific task performance.

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